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1992–1998

to
the U.S. Army Research Office

by
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aimed at developing a new manufacturing technology for thermoplastic composites. On-Line Process Control and NDE Inspection served as the focal point for the development of new in-process NDE technology. Intelligent Control of Integrated Manufacturing Processes integrated the process models developed in the other areas into a knowledge-based system (KBS). Overall, the program was aimed at improving the reliability and extending the useful life of structural components through optimization and control of potentially lower-cost manufacturing processes.

Foreword

In 1986, the Army Research Office, through its University Research Initiative Program, established the ARO/URI Center of Excellence for Manufacturing Science, Reliability, and Maintainability Technology at the University of Delaware Center for Composite Materials (CCM). The program strongly emphasized building quality, long life, predictable and reliable performance, durability, and lower life-cycle costs into thick-section composite systems. In 1992, the Center received a renewal grant from ARO to investigate the manufacturing science of polymeric composites. During the past 10 years, the ARO/URI program has become a core initiative for the Center, resulting in the formation of links with other Army organizations and the establishment of additional collaborative programs.

In establishing the URI center at the University of Delaware in 1986, ARO created a national resource that will serve the needs of the "Army After Next" into the twenty-first century. As a result of this multidisciplinary program of basic research and education, the Center for Composite Materials is well-positioned to serve the needs of the Army with an effective and responsive infrastructure, an awareness of Army needs, an established network of Army and industrial collaborators, and the ARL Composite Materials Research (CMR) Collaborative Program to help sustain the momentum developed under the ARO/URI Program.

The following summarizes quantitatively the accomplishments of the ARO/URI Program at the University of Delaware during the past 10 years (i.e., including Phase and Phase II of the ARO/URI):

- 39 ARO Fellows funded
- 22 Ph.D.s & 16 master's degrees awarded
- 360+ related journal & conference papers
- 3 senior design projects completed for Army customers
- 19 faculty/professional staff participants
- 11 articles on CCM published in *Army RD&A Bulletin*
- 131 related CCM technical reports issued
- 2 colleges, 4 departments involved
- 12 Army labs interacting with CCM
- 9 major programs on which ARO/URI at UD has had a significant impact
- 7 Army scientists in residence
- $1.5M for manufacturing and characterization equipment

Less tangible but nevertheless significant are the following elements of the ARO/URI Program legacy at the University of Delaware:

- Development of a new science base for composites manufacturing, including process simulations
- Establishment of a proactive network with Army labs, industry, and ONR for technology transition/implementation
- Creation of an interdisciplinary teaching/learning environment
- Promotion of team building
- Education and training of U.S. students for government, academic, and industrial positions
- Incorporation of composites-related research into the engineering curriculum
- Enhancement of the undergraduate research experience
- Provision of the basis for new educational tools
- Positioning of the Center to attract additional equipment funding through three DURIP grants

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Statement of the problem studied

The multidisciplinary program focused on developing a manufacturing science base for polymeric composites. The research effort was coordinated through five major thrust areas:

1. The **Advanced Autoclave Molding** area addressed issues of batch-wise in-process monitoring and computer-integrated models; emphasis was placed on coupling reaction chemistry and process control to the mechanical performance of thick-section composites.
2. **Textile Preforming/Resin Transfer Molding** addressed issues of in-process monitoring and computer-integrated models in an approach to developing high-performance, low-cost structures and the basis for studying multi-functional intelligent composites.
3. **Sheet and Stretch Forming** was aimed at developing a new manufacturing technology for thermoplastic composites.
4. **On-Line Process Control and NDE Inspection** served as the focal point for the development of new in-process NDE technology.
5. **Intelligent Control of Integrated Manufacturing Processes** integrated the process models developed in the other areas into a knowledge-based system (KBS).

Overall, the program was aimed at improving the reliability and extending the useful life of structural components through optimization and control of potentially lower-cost manufacturing processes.

Summary of the most important results

Development of a new science base

- Integration of chemistry and mechanics—cure, residual stress and warpage
- Reaction kinetics
- Diffusion/healing
- Interphase mechanisms
- Micromechanics—woven structures, interphase
- Heat transfer/fluid flow
- Permeability
- Sensing

Process simulations

- RTM mold filling
- Resin infusion
- Preform permeability/draping
- Manufacture of multi-step braided composites
- Thick-section cure—autoclave, RTM, microwave
- Automated thermoplastic tow placement

Mechanics of thick-section composites

- Developed a methodology to study process-induced stress and deformation accounting for thermomechanical interaction, thermal and chemical shrinkage, spatial solidification, and arbitrary cross-sectional geometry
- Made significant contribution to the fundamental understanding of thick-section processing
- Identified key role of chemical reaction kinetics
- Coupled cure solidification and shrinkage to residual stress and warpage
- Established foundation for cure-cycle optimization

Influence of the interphase on composite properties

- Developed novel techniques for interrogating properties in the vicinity of the fiber surface
- Demonstrated that property gradients of the matrix exist in the vicinity of the fiber:
  - Thermoplastic property gradients result from entropic segregation of molecular weight.
  - Thermoset property gradients result from stoichiometric imbalance due to diffusion of species to fiber surface.
- Developed models to relate property gradients to local states of residual stress

Textile preforming

- Developed a manufacturing science base of textile composites using braiding, weaving, and knitting processes
- Constructed the relationship between manufacturing processes and the resulting microstructures
- Derived analytical models to predict the thermal, mechanical, and physical properties of textile structural composites
- Developed advanced equipment for fabrication and consolidation of textile composites
- Experimentally verified the predictions of the analytical models

Diffusion-enhanced adhesion (DEA)

- Enables bonding of thermoplastics to thermosets
- Grew out of interphase research
- Focused on Composite Armored Vehicle (CAV)
- Achieved superior ballistic and structural performance as demonstrated by UDLP tests

Rapid fiber placement technology (RAPTECH)

- Established fundamentals for thermoplastic processing in first ARO/URI Program (1986–1991)
- Leveraged DARPA funding for continuation
- Developed comprehensive process simulation
- Implemented advanced model-based control
- Transitioned to industry

Sensing and control

- Developed a fundamental understanding of the relevant issues for an on-line quality sensing system for thermoplastic processes
- Developed a fundamental understanding of the relationship between porosity in composite structures and ultrasonic velocities
- Developed a fundamental understanding of the correlations between ultrasonic amplitudes and automated welding of thermoplastics
- Developed a fundamental understanding and explanation of the onset of ablation in laser-based ultrasonics
- Developed a new inspection method (patent pending) for Gas-Coupled Laser Acoustic Detection (GCLAD)

Flow in molding processes

- Demonstrated that permeability and fabric architecture are tied together
- Demonstrated that micro, macro, and transverse flow physics should be included in RTM filling
- Demonstrated the importance of fabric draping/deformation
- Demonstrated that flow simulations do help in-process control and tool design

Liquid Injection Molding Simulation (LIMS) capabilities

- Faster fill algorithm
- Higher precision
- Reasonable void tracking
- Full control over inlets/outlets during simulation
- Full access to simulation data during simulation
- Programming capability—on-line control simulation, simplification of repetitive tasks
- Automatic tracking of gate and node data during filling
- Direct output to PATRAN/TECPLOT
- Expandable
- Targets PCs and low-end workstations

Education

- Created an interdisciplinary environment
- Promoted team building
- Trained U.S. students for Army, academic, and industrial positions
- Moved research into curricula
- Enhanced undergraduate research experience
- Provided basis for new educational tools—NSF manufacturing education program with MSU, Web-based interactive tutorials

Technology transition/implementation

- Established proactive network
  - Army labs (ARL, TARDEC, ARDEC, MICOM, CRREL, CRDEC, BRDEC, etc.)
  - Office of Naval Research (ONR)
  - Industry
- Serves to identify needs of the Army
- Enhances rapid implementation

List of all publications and technical reports

Journal and proceedings papers

Advani, S. G., "Mold Filling Issues in Liquid Composite Molding Processes: Modeling and Experiments" (invited/keynote lecture), Second Conference on Nondestructive Evaluation Applied to Process Control of Composite Fabrication, St. Louis, MO, October 1–2, 1996.

Advani, S. G., Chapter 1: "Introduction," in *Flow and Rheology in Polymeric Composites Manufacturing*, S. G. Advani, ed., Elsevier Publishers, Amsterdam, pp. 1–8, 1994.

Advani, S. G., editor, *Flow and Rheology in Polymeric Composites Manufacturing*, Elsevier Publishers, Amsterdam, 1994.

Advani, S. G., M. V. Bruschke, and R. Parnas, Chapter 12: "Resin Transfer Molding," *Flow and Rheology in Polymeric Composites Manufacturing*, S. G. Advani, ed., Elsevier Publishers, Amsterdam, pp. 465–516, 1994.

Advani, S. G., S. F. Shuler, and T. S. Creasy, "Non-Linear Rheology of Long Fiber-Reinforced Composites in Sheet Forming," Chapter 8, Sheet Forming of Composites, pp. 323-370, edited by D. Bhattacharrya, Elsevier Publishers, Amsterdam, 1997.

Avgousti, M. and A. N. Beris, "Non-Axisymmetric Modes in the Viscoelastic Taylor-Couette Flow," *Journal of Non-Newtonian Fluid Mechanics*, 50, 225-251, 1993.

Avgousti, M. and A. N. Beris, "Viscoelastic Taylor-Couette Flow: Bifurcation Analysis in the Presence of Symmetries," *Proceedings of the Royal Society of London*, Series A, 443, 17-37, 1993.

Avgousti, M., B. Liu, and A. N. Beris, "Spectral Methods for the Viscoelastic Time-dependent Flow Equations with Applications to Taylor-Couette Flow," *International Journal of Numerical Methods in Fluids*, 17, 49-74, 1993.

Benard, A. and S. G. Advani, " A Cell Model to Describe the Spherulitic Growth in Semi-Crystalline Polymers," *Polymer Engineering and Science*, 36(4), pp. 520–534 (1996).

Benard, A., S. G. Advani, and J. M. Schultz, "Solidification of Semicrystalline Polymers Using a Variable Interface Temperature Model," *Journal of Polymer Science: Polymer Physics Edition*, 34, pp. 471–483 (1996).

Benatar, A., K. Kedward, and J. W. Gillespie Jr., "Joining of Composites," Chapter 12 in *Advanced Composites Manufacturing*, T. G. Gutowski, ed., John Wiley & Sons Publishers, pp. 487–512, 1997.

Beris, A. N. and B. J. Edwards, "On the Admissibility Criteria for Linear Viscoelasticity Kernels," *Rheologica Acta*, 32, 505–510, 1993.

Beris, A. N. and B. J. Edwards, *Thermodynamics of Flowing Systems with Internal Microstructure*, vol. 36 of Engineering and Science series, Oxford University Press, 1994.

Beris, A. N. and D. L. Miller, "Applications of Parallel Computing," *Computers & Chemical Engineering*, 19, R5-R6, 1995.

Beris, A. N. and R. Sureshkumar, "Simulation of Time-Dependent Viscoelastic Channel Poiseuille Flow at High Reynolds Numbers," *Chemical Engineering Science*, 51, 1451–1471, 1996.

Beris, A. N. and V. G. Mavrantzas, "On the Compatibility Between Various Macroscopic Formalisms for the Concentration and Flow of Dilute Polymer Solutions," *Journal of Rheology*, 38, 1235–1250, 1994.

Beris, A. N., M. Avgousti, and A. Souvaliotis, "Spectral Calculations of Viscoelastic Flow: Evaluation of the Giesekus Constitutive Equation in Model Flow Problems," *Journal of Non-Newtonian Fluid Mechanics*, 44, 197–228, 1992.

Bickerton, S. and S. G. Advani "Experimental Investigation and Flow Visualization of Resin Transfer Molding Process in a Non-Planar Geometry," *Composites Science and Technology*, 57, pp. 23–33, 1997.

Bickerton, S. and S. G. Advani, "Characterization of Corner and Edge Permeabilities During Mold Filling in Resin Transfer Molding," in *Recent Advances in Composite Materials*, MD-Vol 56, pp. 143–151, 1995.

Bickerton, S., H. C. Stadtfeld, K. V. Steiner, and S.G. Advani, "Active Control of Resin Injection for the Resin Transfer Molding Process," *Proceedings of the American Society for Composites Thirteenth Technical Conference*, 1998.

Bickerton, S., L. Fong, K. Fickie, and S. G. Advani, "Effect of Draping of Fiber Preforms on Process Parameters During Manufacturing with Resin Transfer Molding," *Proceedings of the 11th Annual ESD Advanced Composites Conference and Exposition*, pp. 213–220, 1995.

Bickerton, S., P. Simácek, and S. G. Advani, "Investigation of Draping and its Effects on Mold Filling During Manufacturing of a Compound Curve Composite Part," *Processing and Manufacturing of Advanced Materials and Structures*, T. J. Moon, et al., eds., ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, November 17–22, 1996.

Bickerton, S., Y. de Parseval, K. Fickie, and S. G. Advani, "Role of Local Permeability Variations in Resin Transfer Molding," *Proceedings of the Ninth International Conference on Numerical Methods in Thermal Problems*, Part 2, pp. 1335–1347, 1995.

Brill, R. P. and G. R. Palmese, "An Investigation of Isothermal Cure Kinetics of Vinyl-Ester/Styrene Bulk Copolymerization Using Fourier Transform Infrared Spectroscopy," *Journal of Applied Polymer Science*, in review, 1998.

Brill, R. P., R. L. McCullough, and G. R. Palmese, "Effect of Resin Formulation and Reaction Temperature on the Curing Kinetics of Vinyl Ester Resins," *Proceedings of the American Society for Composites Eleventh Technical Conference*, Technomic Publishing Co., Inc., Lancaster, PA, 1996.

Bruschke, M. V., T. L. Luce, and S. G. Advani, "Effective In-Plane Permeability of Multi-Layered RTM Preforms," *Proceedings of the American Society for Composites Seventh Technical Conference*, Technomic Publishing Co., Inc., Lancaster, PA, 1992.

Butler, C. A., R. L. McCullough, and J. W. Gillespie Jr., "An Analysis of Mechanisms Governing Fusion Bonding of Thermoplastic Composites," *Journal of Thermoplastic Composite Materials*, Vol. 11, No. 4, pp. 33–363, July 1998.

Byun, J. H. and T-W. Chou, "Development of an Automated 2-Step Braiding Machine and the Process Model," *Innovative Processing and Characterization of Composite Materials*, ASME, NCA-Vol. 20, and AMD-Vol. 211, p. 305, 1995.

Byun, J. H. and T-W. Chou, "Effect of Yarn Twist on the Elastic Properties of Composites," *Proceedings of the 10th International Conference on Composite Materials*, p. IV–293, Woodhead Publishing Ltd., 1995.

Byun, J. H. and T-W. Chou, "Process-Microstructure Relationships of 2-Step and 4-Step Braided Composites," *Composites Science and Technology*, 56, 235, 1996.

Calado, V. M. A. and S. G. Advani, "Effective Permeability of Multi-Layer Preforms in Resin Transfer Molding," *Composites Science and Technology*, vol. 56, pp. 519-531, 1996.

Calado, V. M. A., J. Mogavero, and S. G. Advani, "Effective Average Permeability and Transverse Flow in Multi-Layer Preforms in Resin Transfer Molding," presented at the American Institute of Chemical Engineers Annual Meeting, November 1995.

Caron, J. N., "Laser-Based Generation and Detection of Ultrasonic Waves in Composite Laminates," presented at the 20th Anniversary Research Symposium of the University of Delaware Center for Composite Materials/Ninth ASC Technical Conference, September 20-22, 1994, University of Delaware, Newark, DE.

Caron, J. N., J. B. Mehl, and K. V. Steiner, "Gas-Coupled Laser Acoustic Detection at Ultrasonic and Audio Frequencies," accepted for publication, *Review of Scientific Instruments*, March 1998.

Caron, J. N., J. B. Mehl, and K. V. Steiner, "Laser Ultrasonic Thermoelastic/Ablation Generation with Laser Interferometric Detection in Graphite/Polymer Composites," *Review of Progress in Quantitative Nondestructive Evaluation*, pp. 577–584, vol. 15A, D. O. Thompson and D. E. Chimenti, eds., Plenum Press, New York, 1996.

Caron, J. N., J. B. Mehl, and K. V. Steiner, "Ultrasonic NDE of Composite Panels with Gas-Coupled Laser Acoustic Detection," *Review of Progress in Quantitative NDE*, Vol. 17, edited by D. O. Thompson and D. E. Chimenti, Plenum Press, New York, NY, in press, 1998.

Caron, J. N., Y. Yang, J. B. Mehl, and K. V. Steiner, "Progress in Gas-Coupled Laser Acoustic Detection for NDE Applications," *Review of Progress in Quantitative NDE*, Vol. 18, 1998.

Caron, J. N., Y. Yang, J. B. Mehl, and K. V. Steiner, "Thermoelastic/Ablatic Laser Generated Ultrasound in Graphite/Polymer Composites Detected with a CFP-Based System in Reflection Configuration," *Review of Progress in Quantitative NDE*, Vol. 16A, edited by D. O. Thompson and D. E. Chimenti, Plenum Press, New York, NY, 1997.

Chan, C. Y., A. N. Beris and S.G. Advani, "Simulation of 3-D Hydrodynamic Interactions Around Ellipsoidal Particles Using High Order Boundary Element Techniques," *International Journal of Numerical Methods in Fluids*, 14, 1063–1086, 1992.

Chan, C. Y., A. N. Beris, and S. G. Advani, "Analysis of Periodic 3-D Viscous Flows Using a Quadratic Discrete Galerkin Boundary Element Method," *International Journal of Numerical Methods in Fluids*, 18, pp. 953–981, 1994.

Cheeseman, B. A., M. H., Santare, and B. J. O'Toole, "Flexural Failure of Notched Curved Composite Beams," *Engineering Fracture Mechanics*, Vol. 54, No. 4, pp. 479–98, 1996.

Chou, T-W. and M. Ito, "An Analytical and Experimental Study of the Strength and Failure Behavior of Plain Weave Composites," Journal of Composite Matererials, *32*, 1, 1998.

Chou, T-W. and M. Ito, "Elastic Moduli and Stress Field of a Thin-Film/Substrate System Under an Axisymmetric Loading," International Journal of Solid Structures," 34, p. 4463, 1997.

Chou, T-W., "Recent Advances in the Intelligent Manufacture of Textile Composites," *Progress in Advanced Materials and Mechanics*, Peking University Press, Beijing, China, 1996.

Chou, T-W., "Processing-Microstructure-Property Relationships of Textile Structural Composites," Proceedings of the Third International Symposium on Textile Composites in Building Construction, Seoul, Korea, 1996.

Chou, T-W., "Elastic Properties of Laminates," *Concise Encyclopedia of Composite Materials*, Revised Edition, Elsevier Science Publishers, 1994.

Chou, T-W., "Microstructural Design of Fiber Composites," *Micromechanics of Advanced Materials*, S. N. G. Chu, et al., eds., The Minerals, Metals & Materials Society, Warrendale, PA, p. 413, 1995.

Chou, T-W., "Modeling Damage in Rigid Textile Composite Structures," Paper No. 94–WA/AERO-4, T94 International Mechanical Engineering Congress and Exhibition, Chicago, IL, 1994.

Chou, T-W., "Processing/Microstructure/Property Relationship of Textile Structure Composites" (plenary lecture), Third International Symposium on Textile Composites in Building Construction, Seoul, Korea, November 7–9, 1996.

Chou, T-W., "Properties of Woven Fabric Composites," *Concise Encyclopedia of Composite Materials*, Revised Edition, Elsevier Science Publishers, 1994.

Chou, T-W., "Textile Structural Composites," presented at the Third International Japan SAMPE Conference, Chiba, Japan, December 1993.

Chou, T-W., H. Z. Shan, and A. Parvizi-Majidi, "Numerical Analysis for Design of Composite Specimens for Through-The-Thickness Tensile Measurements," *Journal of Composite Materials*, Vol. 28, p. 1032, 1994.

Chou, T-W., K. Pochiraju, Q-G. Ning, and A. Parvizi-Majidi, "Prediction of Mechanical and Thermal Properties of 3-D Textile Structural Composites," Proceedings of ICCE-I, D. L. Hui, ed., p. 95, 1994.

Creasy, T. and S. G. Advani, "Rheology of Collimated Fiber Composites," ASME AMD, vol. 198, pp. 312–322, New York, 1995.

Creasy, T. S. and S. G. Advani, "Extensional Flow of a Long Discontinuous Fiber Melt Composite System," Processing and Manufacturing of Advanced Materials and Structures, T. J. Moon, et al., eds., ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, November 17-22, 1996.

Creasy, T. S., S. G. Advani, and R. K. Okine, "Non-linear Response of a Long Discontinuous-Fiber/Melt System in Elongational Flows," *Rheological Acta* (submitted October 1995, revised March 1996).

Creasy, T. S., S. G. Advani, and R. K. Okine, "Transient Rheological Behavior of a Long Discontinuous Fiber-Melt System," *Journal of Rheology*, July/August 1996.

De Parseval, Y., R. Valery, and S. G. Advani, "Effect of Local Variations of Preform Permeability on the Average Permeability During Resin Transfer Molding of Composites," SPE Technical Paper 41, pp. 3040–3044, 1995.

Dimitropoulos, C. D. and A. N. Beris, "An Efficient and Robust Spectral Solver for Nonseparable Elliptic Equations," *Journal of Computational Physics*, submitted, 1996.

Edwards, B. J. and A. N. Beris, "The Dynamics of a Thermotropic Liquid Crystal," *Eur. J. Mech. B/Fluids*, 11, 121–142, 1992.

Edwards, B. J. and A. N. Beris, "Poisson Bracket Structures and Rotational Motion in Rigid Particle Systems and Anisotropic Fluid Theory," *Open Systems and Information Dynamics*, in press, 1998.

Edwards, B. J., A. N. Beris, and V. G. Mavrantzas, "A Model with Two Coupled Maxwell Modes," *Journal of Rheology*, 40, 917–942, 1996.

England, K. M., B. K. Fink, and J. W. Gillespie Jr., "In-Situ Sensing of Viscosity by Direct Current Measurements," *Processing and Manufacturing of Advanced Materials and Structures*, T. J. Moon, et al., eds., ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, November 17-22, 1996.

Fecko, D. L., D. Heider, K. V. Steiner, and J. W. Gillespie Jr., "In-Process NDI of Continuous Manufacturing Techniques for Thermoplastic Matrix Composites," *Proceedings of the 1995 NDE of Aging Infrastructure Conference of the International Society for Optical Engineering*, 1995.

Fecko, D. L., J. W. Gillespie, Jr., and K. V. Steiner, "Use of Ultrasonic Lamb Waves for In-Process Porosity Inspection of the Pultrusion Process: Theoretical Velocity Calculations," *Review of Progress in Quantitative Nondestructive Evaluation*, pp. 1231–1238, vol. 15B, D. O. Thompson and D. E. Chimenti, eds., Plenum Press, New York, 1996.

Fecko, D. L., K. V. Steiner, and J. W. Gillespie Jr., "A Novel Technique for the Visualization of Acousto-Ultrasonic Data," *Proceedings of ANTEC 94*, Society of Plastics Engineers, 1994.

Fecko, D. L., K. V. Steiner, and J. W. Gillespie Jr., "Acousto-Ultrasonic Inspection of Pultruded Composites," *Proceedings of the 25th International SAMPE Technical Conference*, SAMPE, Covina, CA, pp. 1189–1195, 1993.

Fecko, D. L., K. V. Steiner, and J. W. Gillespie Jr., "In-Process Non-Destructive Evaluation of the Pultrusion Process," presented at SPIE, May 1995.

Fecko, D. L., K. V. Steiner, and J. W. Gillespie Jr., "Use of Ultrasonic Lamb Waves to Determine Void Content of Composite Specimens," presented at the Ninth ASC Technical Conference, September 20-22, 1994, University of Delaware, Newark, DE.

Fecko, D. L., K. V. Steiner, and J. W. Gillespie Jr., "Void-Related Attenuation of Ultrasonic Energy in Composite Materials," *Review of Progress in Quantitative Nondestructive Evaluation*, Vol. 13B, edited by D. O. Thompson and D. E. Chimenti, Plenum Press, New York, 1994.

Fecko, D. L., K. V. Steiner, R. C. Don, R. Pitchumani, and J. W. Gillespie Jr., "Porosity Modeling for the Thermoplastic Matrix Pultrusion Process," *Proceedings of the 11th Annual Advanced Composites Conference*, pp. 189–201, November 1995.

Feltman, R. S. and M. H. Santare, "A Thermo-Elastic Model for Residual Stress Produced During the On-Line Consolidation of Thermoplastic Composites," *Proceedings of the 1996 NSF Design and Manufacturing Grantees Conference*, pp. 373–374, 1996.

Fink, B. K. and D. S. Kukich, "On Target: Composite Armored Vehicles," in *Modern Applications of Chemistry*, Second Edition, M. P. O'Keefe, ed., McGraw-Hill, Inc., pp. 149–151, 1995.

Fink, B. K., S. M. Walsh, D. C. DeSchepper, R. L. McCullough, R. C. Don, B. J. Waibel, and J. W. Gillespie Jr., "Advances in Resin Transfer Molding Flow Monitoring Using SMARTweave Sensors," *Proceedings of the ASME Materials Division*, vol. 69-2, pp. 999– 1015, 1995.

Finnegan, G. R., "Cure Kinetics of Vinyl Ester Resins," presented at the Ninth ASC Technical Conference, University of Delaware, Newark, DE, September 20-22, 1994.

Fong, L. L. and S. G. Advani, "The Role of Drapability of Fiber Preforms in Resin Transfer Molding," *Proceedings of the Ninth ASC Technical Conference*, Technomic Publishing Company, Lancaster, PA, 1994.

Fong, L., B. Liu, and S. G. Advani, "Modeling and Simulation of Resin Transfer Molding with Flexible Mold Walls," *Proceedings of the Society of the Plastics Industry*, Session 3A, pp. 1–5, 1995.

Gallez, X. and S. G. Advani, "Fast Numerical Simulations for Flow in Liquid Molding Processes," *Proceedings of ANTEC 97*, Society of Plastics Engineers, 1997.

Gallez, X. and S. G. Advani, "Modeling and Simulation of Liquid Composite Processes," presented at Flow Processes in Composite Materials Conference, Wales, United Kingdom, September 1996.

Gallez, X. and S. G. Advani, "Numerical Simulations for Impregnation of Fiber Preforms in Composites Manufacturing," *Proceedings of the Fourth International Conference on Flow Processes in Composite Materials*, Aberystwyth, Wales, September 9–11, 1996.

Gillespie, J. W. Jr. "Academic R&D Review—Highlights of Research Activities at the University of Delaware Center for Composite Materials," Composite Materials Handbook (MIL-HDBK-17) Coordination Meeting, September 9, 1996, Schaumberg, IL.

Gillespie, J. W. Jr. "Joining of Polymer Composites," in *Engineering Analysis of Composites Manufacturing Processes*, T. G. Gutowski, ed., 1993.

Gillespie, J. W. Jr., "Benchmarking CAV Candidate Composite Processing for Six Sigma Methodologies," CAV-ADT PDT Meeting, Warren, MI, December 1994.

Gillespie, J. W. Jr., "Briefing on Rapid Placement Technology for Polymer-Matrix Composites," CAV–ADT PDT Meeting, Warren, MI, December 1994.

Gillespie, J. W. Jr., "Diffusion-Enhanced Adhesive Bonding for Joining S2-PPS Components," CAV–ADT PDT Meeting, Warren, MI, December 1994.

Gillespie, J. W. Jr., "Impact of Affordability Exit Criteria on CAV–ATD," CAV–ADT PDT Meeting, Warren, MI, December 1994.

Gillespie, J. W. Jr., "Interaction Between Healing and Intimate Contact During Fusion Bonding of Thermoplastic Composite Materials," *Proceedings of the American Institute of Chemical Engineers Annual Meeting*, San Francisco, CA, November 13–18, 1994.

Gillespie, J. W. Jr., *New Materials for Next-Generation Commercial Transports*, (contributing author), National Research Council, Publication NMAB-476, National Academy Press, Washington, DC, 1996.

Gillespie, J. W. Jr., R. L. McCullough, and T. A. Bogetti, "Influence of Processing on the Development of Residual Stresses in Thick Section Thermoset Composites," *International Journal of Materials and Product Technology*, accepted, 1996.

Gupte, S. and S. G. Advani, "Flow near the Permeable Boundary of an Aligned Fiber Preform," *Polymer Composites*, 18, pp. 114-124, 1997.

Gupte, S. and S. G. Advani, "Non-Darcy Flow near the Permeable Boundary of a Porous Medium: An Experimental Investigation Using LDA," *Experiments in Fluids*, 22 p. 408–422, 1997.

Hartranft, D., A. P. Majidi, and T-W. Chou, "Modeling and Characterization of Through-the-Thickness Properties of 3D Woven Composites," in *Mechanics of Textile Composites Conference*, NASA Conference Publication 3311, Part 2, C. C. Poe, Jr. and C. E. Harris, eds., p. 251, 1995.

Holmes, S. T. S. H. McKnight, and J. W. Gillespie Jr., "Scaling Issues in Resistance Welded Thermoplastic Composite Joints," *Advances in Polymer Technology*, accepted for publication, 1996.

Hoppel, C. P. R., T. A. Bogetti, and J. W. Gillespie Jr., "Devices for Transmitting High Shear Loads in Composite Structures," *Proceedings of the American Society for Composites 11th Technical Conference on Composite Materials*, Technomic Publishing Co., Inc. Lancaster, PA, 1996.

Hoppel, C. P. R., T. A. Bogetti, and J. W. Gillespie Jr., "Devices for Transmitting High Shear Loads in Composite Structures," *Proceedings of the American Society for Composites 11th Technical Conference on Composite Materials*, Technomic Publishing Co., Inc., Lancaster, PA, 1996.

Hoppel, C. P. R., T. A. Bogetti, and J. W. Gillespie Jr., "Effect of Hydrostatic Pressure on the Mechanical Behavior of Composite Materials," ARL-TR-727, April 1995.

Hoppel, C. P. R., T. A. Bogetti, and J. W. Gillespie Jr., "Literature Review—Effects of Hydrostatic Pressure on the Mechanical Behavior of Composite Materials," *Journal of Thermoplastic Composite Materials*, Vol. 8, pp. 375–409, October 1995.

Hoppel, C. P. R., T. A. Bogetti, and J. W. Gillespie Jr., "The Strength of a Composite Grooved Region," *Proceedings of the American Society for Composites 11th Technical Conference on Composite Materials*, 1996 (also published as ARL-TR-1149, July 1996).

Hrivnak, J. A., "Optimization of Carbon-Fiber Surface Free Energy and Its Effect on Interphase Formation," *Proceedings of the American Society for Composites Ninth Technical Conference*, pp. 761–768, Technomic Publishing Company, Lancaster, PA, 1994.

Hrivnak, J. A., "The Surface Energy of Electrolytically Oxidized Fibers: An Empirical Model," *Proceedings of the American Institute of Chemical Engineers Annual Meeting*, San Francisco, CA, November 13–18, 1994.

Huang, X., J. W. Gillespie Jr., and T. A. Bogetti, "Assessing Thermal Residual Stress in Integral Hybrid Composite Armor," *Proceedings of the ASC 11th Technical Conference*, Technomic Publishing Co., Inc. Lancaster, PA, 1996.

Huang, X., T. A. Bogetti, and J. W. Gillespie Jr., "Cure Simulation and Residual Stress Predictions for Novel Integral Armor Concepts," *Proceedings of the ASC 11th Technical Conference*, Technomic Publishing Co., Inc. Lancaster, PA, 1996.

Huang, X., V. Kumar, L. Gavin, and J. W. Gillespie Jr., "Mechanics of Integral Armor: Discontinuous-Ceramic-Cored Sandwich Structure Under Tension and Shear Loading," *Composite Structures*, Vol. 36, Nos. 1–2, pp. 81–90, 1997.

Immordino, K. M., S. H. McKnight, and J. W. Gillespie Jr., "Characterization of Polysulfone-Epoxy/Amine Interphase For Bonding Thermoplastic Composites," *Proceedings of the 19th Annual Meeting of the Adhesion Society*, February 1996.

Immordino, K. M., S. H. McKnight, and J. W. Gillespie Jr., "In-Situ Evaluation of the Diffusion of Epoxy and Amine in Thermoplastic Polymers," *Proceedings of ANTEC 96*, SPE, 1996.

Ito, M. and T-W. Chou, "Geometrical and Deformation Characteristics of 3-D Braided Composites," *Proceedings of the 10th International Conference on Composite Materials*, p. III-213, Woodhead Publishing Ltd., 1995.

Kalospiros, N. S., B. J. Edwards, and A. N. Beris, "Internal Variables for Relaxation Phenomena in Heat and Mass Transfer," *International Journal of Heat and Mass Transfer*, 36, 1191–1200, 1993.

Karbhari, V. M. and D. S. Kukich, "A Comparative Assessment of Polymeric Composites Technology in the United States and Japan," *Advanced Materials and Processes*, August 1993.

Karbhari, V. M. and D. S. Kukich, "Debunking the Myth: Concurrent Engineering for Composites As a Reality and Not a Management Philosophy," *International Journal of Materials & Product Technology*, Vol. 9, Nos. 1/2/3, pp. 79–104, 1994.

Karbhari, V. M. and R. W. Rydin, "Impact-Resistant Glass Fiber Architectures for Increased Energy Absorption and Structure Survivability Through RTM," *Proceedings of the 1994 SAE International Congress and Exposition*, Detroit, MI (also published as SAE Paper 930170), 1994.

Karbhari, V. M., D. A. Steenkamer, and G. R. Palmese, "Effect of Preform Architecture on Flow and Processing in Resin Transfer Molding," presented at (and published in a Special Publication of) the 1993 SAE International Congress and Exposition, Detroit, March 1-3, 1993.

Karbhari, V. M., S. G. Slotte, D. A. Steenkamer, and D. J. Wilkins, "Effect of Materials, Process, and Equipment Variables on the Performance of RTM Parts," *Composites Manufacturing*, Vol. 3, No. 3, pp. 143-152.

Kordon, A. K., R. Pitchumani, A. N. Beris, V. M. Karbhari, and P. S. Dhurjati, "A Rheological Model for Particulate Ceramic Slurries at Low Temperatures," *Scripta Metallurgica et Materialia*, 29, 1095-1099, 1993.

Kostar, T. D. and T-W. Chou, "Mechanics of Three-Dimensional Textile Structural Composites: Analysis," *Proceedings of NATO Advanced Study Institute Workshop on Mechanics of Composite Materials and Structures*, Trovia, Portugal, July 12–14, 1998.

Kostar, T. D. and T-W. Chou, "Mechanics of Three-Dimensional Textile Structural Composites: Processing," *Proceedings of NATO Advanced Study Institute Workshop on Mechanics of Composite Materials and Structures*, Trovia, Portugal, July 12–14, 1998.

Kostar, T. D. and T-W. Chou, "Braided Structures," 3-D Textile Reinforcements in Composite Materials, ed. by A. Miravete, Woodhead Publishing Ltd., submitted.

Kostar, T. D., T-W. Chou, and P. Popper, "Characterization and Comparative Study of Three-Dimensional Braided Hybrid Composites," *Journal of Materials Science*, submitted.

Kostar, T. D., T-W. Chou, and P. Popper, "A Methodology for Cartesian Braiding of Three-Dimensional Shapes and Special Structures," *Composites Part A*, submitted.

Kostar, T. D. and T-W. Chou, "Computer Synthesis of Fiber Architecture and Properties of Textile Structural Composites," *Proceedings of the US-Russian Workshop on Computer Synthesis of Structures and Properties of Fiber Composites*, Russian Academy of Sciences, Moscow, Russia, p. 86, May 1995.

Kostar, T. D. and T-W. Chou, "Design and Automated Fabrication of 3-D Braided Preforms for Advanced Structural Composites," *Proceedings of the Third International Conference on Computer-Aided Design in Composite Material Technology (CADCOMP '92)*, 1992.

Kostar, T. D. and T-W. Chou, "Design of Three-Dimensional Multi-Step Hybrid Composites of Complex Shapes," *Proceedings of the ASME International Mechanical Engineering Congress and Exposition*, Atlanta, GA, 1996.

Kostar, T. D. and T-W. Chou, "Simulation, Design, and Fabrication of Advanced Three-Dimensional Braided Preforms," *Proceedings of the Ninth International Conference on Composite Materials (ICCM 9)*, Madrid, Spain, July 12–16, 1993.

Kostar, T. D., and T-W. Chou, "Microstructural Design of Advanced Three-Dimensional Braided Preforms," *Journal of Composite Materials*, Vol. 28, No. 13, pp. 1180–1201, 1994.

Kostar, T. D., and T-W. Chou, "Process Simulation and Fabrication of Advanced Step Three-Dimensional Braided Preforms," *Journal of Materials Science*, Vol. 29, pp. 2159–2167, 1994.

Kostar, T. D., and T-W. Chou, "Process-Microstructure-Property Relationship of Textile Structural Composites," *Proceedings of the 8th CIMTEC-World Ceramics Congress and Forum on New Materials*, Florence, Italy, 1994.

Kostar, T. D., J. H. Byun, and T-W. Chou, "Design-Fabrication-Performance Relationship of Advanced Textile Structural Composites," in *Advanced Technology for Design and Fabrication of Composite Materials and Structures*, G. C. Sih, A. Carpinteri, and G. Surace, eds., Kluwer Academic Publishers, p. 63, 1995.

Krach, A. and S. G. Advani, "Influence of Void Shape, Void Volume and Matrix Anisotropy on Effective Thermal Conductivity of a Three-Phase Composite," *Journal of Composite Materials*, vol. 30, No. 8, 1996.

Kukich, D. S., "ARL, University of Delaware Collaborate on New Composite Armor Process, "*Army RD&A Bulletin*, pp. 31–32, April–May 1997.

Kukich, D. S., "Composite Materials Research, Education, and Technology Transfer at the University of Delaware Center for Composite Materials (UD–CCM)," *Polymer News*, vol. 21, no. 5, pp. 174–179, May 1996.

Kukich, D. S., "Composites for Bridging and Infrastructure Renewal," *Army RD&A Bulletin*, pp. 30–33, March–April 1994.

Kukich, D. S., "Intelligent Resin Transfer Molding for Integral Armor Applications," *Army RD&A Bulletin*, pp. 42–43, January–February 1996.

Kukich, D. S., "MIL-HDBK-17: Expanding to New Application Areas," Guest Editorial, *The AMPTIAC Newsletter*, Vol. 1, No. 3, 1997.

Kukich, D. S., "Nondestructive Evaluation—A Critical Step in the Production of Quality Composite Parts," *Army RD&A Bulletin*, pp. 11–14, May–June 1994.

Kukich, D. S., "Resin Transfer Molding: Tailorable Composites Manufacturing," *Army RD&A Bulletin*, pp. 15-18, July–August 1993.

Kukich, D. S., "Robotic Filament Winding Composites Manufacturing," *Army RD&A Bulletin*, pp. 40–41, September–October 1994.

Kukich, D. S., "Six Sigma: A Route to Quality and Affordability," *Army RD&A Bulletin*, March–April 1997.

Kukich, D. S., "Textile Structural Composites: A Route to Enhanced Wear Resistance, Fracture Toughness, and Damage Tolerance," *Army RD&A Bulletin*, pp. 15–17, July–August 1995.

Kukich, D. S., "The Army Center of Excellence for Composite Materials," *Army RD&A Bulletin*, pp. 1-5, July-August 1992.

Kukich, D. S., "Welding of Composite Materials," *Army RD&A Bulletin*, pp. 11-13, March–April 1993.

Kulkarni, J. A. and A. N. Beris, "A Model for the Necking Phenomenon in High-Speed Fiber Spinning Based on Flow-Induced Crystallization," *Journal of Rheology*, 42, 971–994, 1998.

Lang, E. J., and T-W. Chou, "The Effect of Strain Gage Size on the Measurement Errors in Textile Composite Materials," *Composites Science and Technology*, in press

Lang, E. J., and T-W. Chou, "The Effect of Strain Gage Size on the Measurement Errors in Textile Composite Materials," *Proceedings of the Eleventh International Conference on Composite Materials*, Australian Composite Structures Society, Woodhead Publishing Ltd., Vol. 5, p. V-1, 1997.

Lang, E. J., and T-W. Chou, "Lineal Sensor Constitutive Relations and Textile Composites," *Journal of Intelligent Material Systems and Structures*, in press.

Lang, E. J., and T-W. Chou, "Arrays of Lineal Strain Sensors in Textile Preforms," *Journal of Sound and Vibration*, in press.

Lang, E. J., and T-W. Chou, "Modal Filtering Using Lineal Sensors," *Proceedings of the 35th AIAA/ASME/ASCE/AHS/ASC-SDM Conference*, Hilton Head, SC, Paper No. AIAA-94–1741-CP, p. 95, 1994.

Li, J. and T-W. Chou, "Elastic Field of a Thin-Film/Substrate System Under an Axisymmetric Loading," *International Journal of Solids Structures*, in press, 1998.

Li, J., E. T. Thostenson, A. J. Hsieh, and T-W. Chou, "Analytical and Experimental Studies of Nanoindentation of Thin-Film Coating/ Substrate Systems," MRS Spring Meeting, San Francisco, CA, March 31–April 4, 1997.

Li, J., E. T. Thostenson, L. Riester, and T-W. Chou, "Investigation of Thin-Film Coating/Substrate Systems by Nanoindentation," *Journal of Engineering Materials Technology*, 120, 154, 1998.

Lin, H. R. and S. G. Advani, "Processing Models and Characterization of Thermoplastic Composite Wound Parts," *Polymer Composites*, 18,pp. 405–411, 1997.

Liu, D., S. Bickerton, and S. G. Advani, "Modeling and Simulation of RTM: Gate Control, Venting and Dry Spot Prediction," *Composites Part A*, 27A, pp. 135–141, 1996.

Luce, T. L., S. G. Advani, J. G. Howard, and R. S. Parnas, "Permeability Characterization, Part 2: Flow Behavior in Multiple-Layer Preforms," *Polymer Composites*, 16, pp. 437–458, 1995.

Maier, R. S., T. F. Rohaly, S. G. Advani, and K. D. Fickie, "A Fast Numerical Method for Isothermal Resin Transfer Mold Filling," *International Journal of Numerical Methods in Engineering*, 39 pp. 1405–1422, 1996.

Mavrantzas, V. G. and A. N. Beris, "Modeling the Surface Effects on the Structure and the Rheology of Polymer Solutions: A) General Formulation with Application to a Neutral Surface," *Macromolecules*, submitted, 1996.

Mavrantzas, V. G. and A. N. Beris, "Modeling the Surface Effects on the Structure and the Rheology of Polymer Solutions: B) Application to an Adsorbing Surface," *Macromolecules*, submitted, 1996.

Mavrantzas, V. G. and A. N. Beris, "Modeling of the Rheology and Flow-Induced Concentration Changes in Polymer Solutions," *Physical Review Letters*, 69, 273-276, 1992, & (Erratum) **70**, 2659, 1992.

Mavrantzas, V. G. and A. N. Beris, "Theoretical Study of the Effects of Polymer-Wall Interaction on the Rheology of Dilute Polymer Solutions," *Journal of Rheology*, 36, 175-213, 1992.

Mavrantzas, V. G., A. Souvaliotis, and A. N. Beris, "Pseudospectral Calculations of Stress-Induced Concentration Changes in Viscometric Flows of Polymer Solutions," *Theoretical & Computational Fluid Dynamics*, 5, 3-31, 1993.

McCullough, R. L., "Design of Cure Cycles for RTM," presented at the Second Joint Composites Workshop on Manufacturing Science: Molding Processes, Lansing, MI, October 25, 1996.

McCullough, R. L., "Interphase Zones in Polymeric Composites," *Polymer Composites: Molecular and Micromechanical*, Akron, OH, May 24–25, 1993.

McKnight, S. H. and J. W. Gillespie Jr., "In Situ Examination of Water Diffusion to the Polypropylene-Silane Interface Using FTIR-ATR," *Journal of Applied Polymer Science*, Vol. 64, No. 10, June 6, 1997.

McKnight, S. H. and J. W. Gillespie Jr., "Non-Chromate Surface Treatments of Aluminum for Adhesive Bonding to Composite Materials," *Proceedings of International Conference on Composite Materials and Energy*, pp. 364–372, 1995.

McKnight, S. H. and J. W. Gillespie Jr., "Silane Coupling Agents as Adhesion Promoters for Bonding Thermoplastic Polymers to Aluminum," *Proceedings of the 18th Annual Meeting of the Adhesion Society*, 1995.

McKnight, S. H., R. C. Don, M. Scott, A. D. Braem, and J. W. Gillespie Jr., "Experimental Investigation of Diffusion Enhanced Adhesive Bonding for Thermoplastic Composites," *Proceedings of ANTEC 95*, Society of Plastics Engineers, 1995.

Michaud, D. J., "Investigation of Curing Behavior in Thick Thermoset Composites Manufactured By Resin Transfer Molding," Masters Thesis, Department of Chemical Engineering, University of Delaware, Newark, DE, 1996.

Michaud, D. J., A. N. Beris and P. S. Dhurjati, "Curing Behavior of Thick-Sectioned RTM Composites," *Journal of Composite Materials*, in press, 1998.

Michaud, D. J., A. N. Beris, and P. S. Dhurjati, "Kinetic Behavior of a Vinyl-Ester Resin Within a Thick-Sectioned Composite," 1996 American Institute of Chemical Engineers Annual Meeting, Chicago, IL, November 13, 1996.

Mogavero J. and S. G. Advani, "Experimental Investigation of Flow Through Multi-Layered Preforms," *Polymer Composites*, 18, pp. 649–655, 1997.

Mogavero J., J. Sun, and S. G. Advani, "Non-Linear Control of the Resin Transfer Molding Process," *Polymer Composites*, 18, pp. 200-217, 1997.

Ning, Q. G. and T-W. Chou, "A Closed-Form Solution of the Transverse Effective Thermal Conductivity of Woven Fabric Composites," *Journal of Composite Materials*, 29, 2280, 1995.

Ning, Q. G. and T-W. Chou, "Closed Form Solutions for the In-Plane Effective Thermal Conductivity of Woven Fabric Composites," *Composites Science and Technology*, 55, 41, 1995.

Ning, Q. G. and T-W. Chou, "Effective Transverse Electrical Permittivities of Plain Weave, Twill Weave, and Satin Fabric Composites," in *Electrically Based Microstructural Characterization*, Materials Research Society, Pittsburgh, PA, vol. 411, 1996.

Ning, Q.-G. and T-W. Chou, "Analytical Characterization of Thermal and Dielectric Properties of Woven Fabric Composites," *Proceedings of the 10th International Conference on Composite Materials*, p. IV-465, 1995, Woodhead Publishing Ltd., 1995.

Ning, Q-G., D. G. Hwang, and T-W. Chou, "Effective Transverse Thermal Conductivities of Plain Weave, Twill Weave, and Four-Harness Satin Weave Composites," in *Innovative Processing and Characterization of Composite Materials*, ASME, NCA-vol. 20 and AMD-vol. 211, p. 343, 1995.

Palmese, G. R., "Copolymerization Kinetics of Styrene/Vinyl-Ester Systems at Low Cure Temperatures," *Journal of Polymer Science*, Part A: Polymer Chemistry, in review, 1998.

Palmese, G. R., N. R. Sottos, and R. L. McCullough, "Relationship Between Interphase Composition, Material Properties, and Residual Thermal Stresses in Composite Materials," *Journal of Adhesion*, vol. 52, pp. 101–113, 1995.

Palmese, G. R., R. P. Brill, and R. L. McCullough, "Interphase Formation in Vinyl-Ester Composites," presented at the 1996 American Institute of Chemical Engineers Annual Meeting, Chicago, IL, November 13, 1996.

Palmese, G. R., R. P. Brill, and S. Ziaee, "The Relationship Among Processing, Structure, and Performance of Vinyl-Ester Resins," presented at the 1996 American Institute of Chemical Engineers Annual Meeting, Chicago, IL, November 13, 1996.

Parnas, R. S., A. J. Salem, T. A. K. Sadiq, H. P. Wang, and S. G. Advani, "The Interaction Between Micro- and Macroscopic Flow in RTM Preforms," *Composite Structures*, 27, pp. 93–107, 1994.

Parnas, R. S., J. G. Howard, T. L. Luce, and S. G. Advani, "Permeability Characterization, Part 1: A Proposed Standard Reference Material for Permeability Characterizations," *Polymer Composites*, 16, pp. 430–445, 1995.

Pilitsis, S. and A. N. Beris, "Pseudospectral Calculations of Viscoelastic Flow in a Periodically Constricted Tube," *Comp. Meth. in Appl. Mech. and Engrg.*, 98, 307-328, 1992.

Pillai, K. M. and S. G. Advani, "Modeling of Void Migration in Resin Transfer Molding Process," *Processing and Manufacturing of Advanced Materials and Structures*, T. J. Moon, et al., eds., ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, November 17–22, 1996.

Pillai, K. M. and S. G. Advani, "Numerical and Analytical Study to Estimate the Effect of Two Length Scales Upon the Permeability of a Fibrous Porous Medium," *Transport in Porous Media*, 21(1), pp. 1–17, 1995.

Pillai, K. M., T. L. Luce, M. V. Bruschke, and S. G. Advani, "Modeling the Heterogeneities Present in Preforms During Mold Filling in RTM," *Proceedings of the 25th International SAMPE Technical Conference*, SAMPE, Covina, CA, 1993.

Pillai, K. M., T. L. Luce, M. V. Bruschke, R. S. Parnas, and S. G. Advani, "A Two-Layer Model of Permeability in the Unsaturated Flow Regime for a Woven RTM Preform," *Proceedings of the American Society for Composites Ninth Technical Conference*, pp. 141–150, Technomic Publishing Company, Lancaster, PA, 1994.

Pillai, V. K., A. N. Beris, and P. S. Dhurjati, "Implementation of Model-Based Optimal Temperature Profiles for Autoclave Curing of Composites Using a Knowledge-Based System," *Ind. Eng. Chem. Res.*, 33, pp. 2443–2452, 1994.

Pillai, V. K., A. N. Beris, and P. S. Dhurjati, "Intelligent Control of an Autoclave Cure Process Using an Expert System," presented at ISA '93 Chicago, September 19–24, 1993.

Pillai, V. K., A. N. Beris, and P. S. Dhurjati, "Novel Method for Optimization of Batch Processes," *Computers and Chemical Engineering*, May 1993.

Pillai, V., A. N. Beris and P. Dhurjati, "Heuristics-Guided Optimization of Batch Processes," Computers & Chemical Engineering, 20, 275-294, 1996.

Pillai, V., A. N. Beris, and P. S. Dhurjati, "Intelligent Curing of Thick Composites Using a Knowledge-Based System," *Journal of Composite Materials*, 31, 22–51.

Pipes, R. B., D. W. Coffin, P. Simácek, S. F. Shuler and R. K. Okine, "Rheological Behavior of Collimated Fiber Thermoplastic Composite Materials," Chapter 4 in *Flow and Rheology in Polymer Composites Manufacturing*, S. G. Advani, ed., Elsevier, pp. 87-126 1994.

Pipes, R. B., D. W. Coffin, S. F. Shuler and P. Simácek, "Non-Newtonian Constitutive Relationships for Hyperconcentrated Fiber Suspensions," *Journal of Composite Materials*, Vol. 28, No. 4, 1994.

Pipes, R. B., D. W. Coffin, S. F. Shuler, P. Simácek and T. S. Creasy, "More on the Rheological Behavior of Collimated Fiber Thermoplastic Composite Materials," *Proceedings of the American Society for Composites Seventh Technical Conference on Composite Materials*, Technomic Publishing Co., Inc., Lancaster, PA October, 1992.

Pitchumani, R., A. K. Kordon, A. N. Beris, V. M. Karbhari, P. S. Dhurjati, B. Rossing and W. Johnson, "Thermofluid Analysis and Design of a Low-Temperature Performing Process," *Metallurgical Transactions B*, 25b, 761-771, 1994.

Pitchumani, R., J. W. Gillespie Jr., and M. A. Lamontia, "Design and Optimization of a Thermoplastic Tow-Placement Process with In-situ Consolidation," *Journal of Composite Materials*, Vol. 31, No. 3, pp. 244–275, 1997.

Pochiraju, K., B. M. Shah, and T-W. Chou, "Experimental Characterization of 3-D Woven and Braided Composites," *Proceedings of the 37th AIAA/ASME/ASCE/ AHS/ASL Structures, Structural Dynamics and Materials Conference*, CP962, p. 908, 1996.

Qaissaunee, M. T. and M. H. Santare, "Microcracking in Composites with an Interphase Region," *Proceedings of the 25th International SAMPE Technical Conference*, SAMPE, Covina, CA, pp. 995-1007, 1993.

Qaissaunee, M. T., and M. H. Santare, "Edge Dislocation Interacting With an Elliptical Inclusion Surrounded by an Interfacial Region," *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 48, Part 3, pp. 465–482, 1995.

Rajagopalan, G., S. H. McKnight, and J. W. Gillespie Jr., "Interdiffusion in a Poly-aryl-ether-ether-ketone (PEEK)/Epoxy System," *Proceedings of ANTEC 96*, Society of Plastics Engineers, 1996.

Ramakrishna, S., H. Hamada, and T-W. Chou, "Impact Damage Resistance of Knitted Fabric Reinforced Polypropylene Composite Laminates," *Journal of Science and Engineering of Composites*, 4, p. 61, 1995.

Ranganathan S. , R. G. Easterling, S. G. Advani, and F. Phelan, "Evaluating the Effect of Micro-structural Variations on the Permeabilities of a Porous Medium, Polymers & Polymer Composites, vol. 6 no. 2, pp. 63–73, 1998.

Ranganathan, S., F. Phelan, and S. G. Advani, "A Generalized Model for the Transverse Permeability of Unidirectional Fibrous Media," *Polymer Composites* 17, pp. 222-230, 1996.

Ranganathan, S., F. Phelan, and S. G. Advani, "Microstructure-Permeability Predictions for the Processing of Advanced Composites," SPE Technical Paper 41, pp. 3035–3039, 1995.

Ranganathan, S., S. G. Advani, and M. A. Lamontia, "A Non-isothermal Process Model for Consolidation and Void Reduction During In-situ Tow Placement of Thermoplastic Composites," *Journal of Composite Materials*, 29, pp. 1040–1062, 1995.

Renardy, M., Y. Renardy, R. Sureshkumar and A. N. Beris, "Hopf-Hopf and Steady-Hopf Interactions in Taylor-Couette Flow of an Upper-Convected Fluid," *Journal of Non-Newtonian Fluid Mechanics*, 63, 1-31, 1996.

Richards, J. R., A. M. Lenhoff, and A. N. Beris, "Dynamic Breakup of Liquid-Liquid Jets," *Physics of Fluids*, 6, 2640–2655, 1994.

Richards, J. R., A. N. Beris, and A. M. Lenhoff, "Drop Formation in Liquid-Liquid Systems Before and After Jetting," *Physics of Fluids*, 7, 2617–2630, 1995.

Richards, J.R., A. N. Beris and A. M. Lenhoff, "Steady Laminar Flow of Liquid-Liquid Jets at High Reynolds Numbers," *Physics of Fluids A*, 5, 1703–1717, 1993.

Rosselli, F. and M. H. Santare, "Comparison of the Short Beam Shear (SBS) and the Interlaminar Shear Device (ISD) Tests," *Composites Part A*, Vol. 28A, pp. 587–94, 1997.

Rosselli, F. and M. H. Santare, "Interlaminar Strength of Thermoplastic Composite Rings Manufactured Using Laser-Assisted On-Line Consolidation," *Proceedings of the 1996 NSF Design and Manufacturing Grantees Conference*, pp. 431–432, 1996.

Rydin, R. W. and V. M. Karbhari, "Impact Resistant Glass Fiber Architectures for Increased Energy Absorption and Structure Survivability Through RTM," presented at the 1993 SAE International Congress and Exposition, Detroit, MI, March 1-5, 1993, and published as SAE paper 930170, 1993.

Rydin, R. W., "The Use of Inelastic Energy Curves for Determination of Impact Response of RTM Composites," presented at the 20th Anniversary Research Symposium of the University of Delaware Center for Composite Materials/Ninth ASC Technical Conference, University of Delaware, Newark, DE, September 20-22, 1994.

Rydin, R. W., A. LoCurcio, and V. M. Karbhari, "Influence of Reinforcing Layer Orientation on Impact Response of Plain Weave RTM Composites," *Journal of Reinforced Plastics and Composites*, vol. 14, no. 11, pp. 1199–1225, November 1995.

Rydin, R. W., and V. M. Karbhari, "A Description of Impact-Induced Damage Mechanisms in RTM Composites," *Proceedings of the 10th ASM/ESD Advanced Composites Conference and Exposition*, Detroit, MI, pp. 117–124, 1994.

Rydin, R. W., and V. M. Karbhari, "Effect of Fabric Architecture on the Impact Response of RTM Composites: Use of Novel Metrics," *Proceedings of the 40th International SAMPE Symposium and Exhibition*, May 8–11, Anaheim, CA, 1995.

Rydin, R. W., and V. M. Karbhari, "Inelastic Energy Curves: A Tool for Evaluating the Impact Response of Composite Plates," *Journal of Reinforced Plastics and Composites*, vol. 14, no. 11, pp. 1175–1198, November 1995.

Rydin, R. W., M. B. Bushman, and V. M. Karbhari, "The Influence of Velocity in Low-Velocity Impact Testing of Composites Using the Drop Weight Impact Tower," *Journal of Reinforced Plastics and Composites*, Vol. 14, pp. 113–127, February 1995.

Rydin, R. W., P. C. Varelides, C. D. Papaspyrides, and V. M. Karbhari, "Modifying Energy Absorption in Composites Using Polyamide Coated Glass Fabric, *Proceedings of the ASM-ESD Advanced Composites Conference and Exposition*, Dearborn, MI, November 1995.

Rydin, R. W., P. C. Varelides, C. D. Papaspyrides, and V. M. Karbhari, "Glass Fabric Vinyl-Ester Composites: Tailoring the Fiber Bundle/Matrix Interphase with Nylon Coatings to Modify Energy Absorption Behavior," accepted, *Journal of Composite Materials*, 1996.

Shan, H. Z. and T-W. Chou, "Transverse Elastic Constants of Unidirectional Fiber Composites with Interfacial Debonding," *Composites Science and Technology*, vol. 53, p. 383, 1995.

Shuler, S. and S. G. Advani, "Transverse Squeeze Flow of Concentrated Aligned Fibers in Viscous Fluids, *Journal of Non-Newtonian Fluid Mechanics*, 65 pp. 47–74, 1996.

Shuler, S. and S. G. Advani, "Anisotropy Issues in Sheet Forming of Thermoplastic Fiber Reinforced Laminates," *Proceedings of the 11th Annual ESD Advanced Composites Conference and Exposition*, pp. 467–490, 1995.

Shuler, S. and S. G. Advani, "Flow Instabilities During the Squeeze Flow of MultiAxial Laminates," *Journal of Composite Materials* 31, pp.2146–2160, 1997.

Shuler, S. F., D. M. Binding, and R. B. Pipes. "Rheological Behavior of Two- and Three-Phase Fiber Suspensions," *Polymer Composites*, Vol. 15, No. 6, December 1994.

Shuler, S. F., R. B. Pipes, D. W. Coffin, P. Simácek, and R. K. Okine, "Rheological Behavior of Collimated Fiber Thermoplastic Composite Materials," *Flow Phenomena in Polymeric Composites*, S. G. Advani, ed., Elsevier, 1994.

Shuler, S. F., S. G. Advani, and R. B. Pipes, "Squeeze Flow Behavior of Laminates Composed of Long Aligned Fibers Within a Thermoplastic Matrix," *Proceedings of the Society of Rheology 6th Annual Meeting*, Philadelphia, PA, October 2–6, 1994.

Simacek, P. and S. G. Advani, "Permeability Model for a Woven Fabric," *Polymer Composites* 17, pp. 887–899, 1996.

Souvaliotis A. and A. N. Beris, "An Extended White-Metzner Viscoelastic Fluid Model Based on an Internal Structural Parameter," *Journal of Rheology*, 36, 241-271, 1992.

Souvaliotis, A. and A. N. Beris, "Application of Domain Decomposition Pseudospectral Methods to Viscoelastic Flow Simulations," *Journal of Rheology*, 36, 1417-1453 (1992).

Souvaliotis, A. and A. N. Beris, "Spectral Collocation/Domain Decomposition Method for Viscoelastic Flow Simulations in Model Porous Geometries," *Comput. Meth. Appl. Mech. Engrg.*, 129, 9-28, 1996.

Stark, S. and A. N. Beris, "LU Decomposition Optimized for a Parallel Computer with a Hierarchical Distributed Memory," *Parallel Computing*, 18, 959-971, 1992.

Steenkamer, D. A., D. J. Wilkins, and V. M. Karbhari, "Influence of Test Fluid on Fabric Permeability Measurements and Implications to Processing of Liquid Molded Composites," *Journal of Materials Science Letters*, 12, pp. 971–973, 1993.

Steenkamer, D. A., D. J. Wilkins, and V. M. Karbhari, "Resin Transfer Molding I: Materials and Preforming," *Processing of Advanced Materials*, 3[2], pp. 89–105, 1993.

Steenkamer, D. A., D. J. Wilkins, and V. M. Karbhari, "Resin Transfer Molding II: Tooling and Processing," *Processing of Advanced Materials*, 3[3], pp. 181–192, 1993.

Steiner, K. V. and T. C. Lindsay, "Correlation of Full-Waveform Ultrasonic NDE Data and Low-Velocity Impact Damage to Composite Panels," *Review of Progress in Quantitative Nondestructive Evaluation*, Vol. 13B, edited by D. O. Thompson and D. E. Chimenti, Plenum Press, New York, pp. 1283–1290, 1994.

Steiner, K. V., "Experiences, Processing, Control, and Performance of Composite Parts made with RTM and VARTM Techniques," (invited keynote presentation), Symposium on the Use of Composites for Aerospace Applications, Federal Academy for Defense Materiel and Defense Technology (WIM), Erding, Germany, November 5–7, 1996.

Steiner, K. V., "On-line NDE and Monitoring of Composites Manufacturing," *Materials World*, Vol. 6, No. 6, 1998.

Steiner, K. V., "Volumetric Visualization of Ultrasonic NDE of Composites," *Proceedings of the American Society for Composites Ninth Technical Conference*, pp. 238–245, Technomic Publishing Company, Lancaster, PA, 1994.

Steiner, K. V., K. Krieger, J. B. Mehl, J. N. Caron, and Y-C. Yang, "Infrared Thermography and Laser-based Ultrasonic Methods for On-line Porosity Sensing During Thermoplastic Composites Fabrication," NTIAC Second Conference on NDE Applied to Process Control of Composite Fabrication, St. Louis, MO, October 1996.

Steiner, K. V., R. C. Don, and J. W. Gillespie Jr., "On-Line Process Control Issues for Automated Tow Placement of Thermoplastic Composites," *Processing and Manufacturing of Advanced Materials and Structures*, T. J. Moon, et al., eds., ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, November 17-22, 1996.

Steiner, K. V., R. F. Eduljee, X. Huang, and J. W. Gillespie Jr., "Ultrasonic NDE Techniques for the Evaluation of Matrix Cracking in Composite Laminates," *Journal of Composite Science & Technology*, Vol. 53, No. 2, Elsevier Science Ltd, 1995.

Steiner, K.V., J. B. Mehl, J. N. Caron, Y. Yang, and K. Krieger, "Infrared Thermography and Laser-based Ultrasonic Methods for On-line Porosity Sensing During Thermoplastic Composites Fabrication," Second Conference on NDE Applied to Process Control of Composite Fabrication, October 1996.

Steiner, K.V., J. N. Caron, Y-C. Yang, and J. B. Mehl, "Recent Developments Using Laser-Ultrasonics Methods for on-line Inspection of Composites Structures," presented at the 4th International Conference on Composites Engineering, Kona, HI, July 1997.

Sureshkumar and A. N. Beris, "On the Flow Simulations of Dilute Polymer Solutions with Non-Linear Kinetic Theory Based Constitutive Models," *Proceedings of the XIIth International Congress on Rheology*, A. Ait-Kadi, J. M. Dealy, D. F. James and M. C. Williams, eds., Quebec City, Quebec, August 18–23, p. 205, 1996.

Sureshkumar, R. and A. N. Beris, "Linear Stability Analysis of Viscoelastic Poiseuille Flow Using an Arnoldi-Based Orthogonalization Algorithm," *Journal of Non-Newtonian Fluid Mechanics*, 56, 151–182, 1995.

Sureshkumar, R. and A. N. Beris, "Uniformly Valid Approximations for the Conformational Integrals Resulting from Gaussian Closure in the Hookean Dumbbell Model with Internal Viscosity," *Journal of Rheology*, 39, 1361–1384, 1995.

Sureshkumar, R. and A. N. Beris, "Effect of Artificial Stress Diffusivity on the Stability of Numerical Calculations and the Flow Dynamics of Time-Dependent Viscoelastic Flows," *Journal of Non-Newtonian Fluid Mechanics*, 60, 53–80, 1995.

Sureshkumar, R. and A. N. Beris, "Numerical Simulations of Three-Dimensional and Time-Dependent Viscoelastic Flows with Applications to Turbulent Drag Reduction," *Proceedings of the XIIth International Congress on Rheology*, A. Ait-Kadi, J. M. Dealy, D. F. James and M. C. Williams, eds., Quebec City, Quebec, August 18–23, 411–412, 1996.

Sureshkumar, R., A. N. Beris and R. A. Handler, "Direct Numerical Simulation of the Turbulent Channel Flow of a Polymer Solution," *Physics of Fluids*, 9, 743-755, 1996.

Sureshkumar, R., A. N. Beris, and R. A. Handler, "Direct Numerical Simulation of Polymer-Induced Drag Reduction in Turbulent Channel Flow," *Physics of Fluids*, Vol. 9, 743–755, 1997.

Tackitt, K. D. and J. W. Gillespie Jr., "Through-Transmission Ultrasonics for Process Monitoring of Thermoplastic Fusion Bonding, *Proceedings of the 11th Annual Technical Conference on Composites*, Technomic Publishing Co., Inc., Lancaster, PA, 1996.

Tackitt, K. D., "A Model of the Temperature Dependence of Sound Transmission Through Layered Structures," presented at the 20th Anniversary Research Symposium of the University of Delaware Center for Composite Materials/Ninth ASC Technical Conference, University of Delaware, Newark, DE, September 20-22, 1994.

Tackitt, K. D., C. A. Butler, R. C. Don, J. W. Gillespie Jr., and R. L. McCullough, "Assessment of Through Transmission Ultrasonics for the Detection of Intimate Contact During Bonding," *Proceedings of ANTEC 95*, Society of Plastics Engineers, May 1995.

Tackitt, K. D., J. N. Caron, J. W. Gillespie Jr., J. B. Mehl, "High Temperature Measurements of Ultrasonic Wave Speed Using A Laser Ultrasonic Technique," *Proceedings of ANTEC 96*, Society of Plastics Engineers, 1996.

Tackitt, K. D., R. C. Don, and J. W. Gillespie Jr., "A Model for the Transmission of Ultrasound During the Fusion Bonding of Composites," *Proceedings of the 10th Annual ASM/ESD Advanced Composites Conference and Exposition*, Detroit, MI, ASM International, 1994.

Tackitt, K. D., R. C. Don, and J. W. Gillespie Jr., "Modeling Through-Transmission Ultrasonics for Controlling the Fusion Bonding of Composites," *Proceedings of the 21st Annual Review of Progress in Quantitative Nondestructive Evaluation*, Snowmass, CO, Plenum Press, 1994.

Tackitt, K. D., R. C. Don, and S. T. Holmes, "Through-Transmission Ultrasonics for Process Control of a Thermoplastic Fusion Bonding Process," *Proceedings of ANTEC 93*, Society of Plastics Engineers, 1993.

Thomas, G. E. , R. F. Eduljee, and J. W. Gillespie Jr., "An Affordable Weapon Station Through the Application of Six Sigma," *Proceedings of the 11th DoD/NASA/FAA Conference on Fibrous Composites in Structural Design*, Fort Worth, TX, August 26–29, 1996.

Thostenson, E. T. and T-W. Chou, "Microwave Processing of Thick-Section Composite Materials," *Proceedings of the American Society for Composites Twelfth Technical Conference*, pp. 931-940, Technomic Publishing Company, Inc., Lancaster, PA, 1997.

Tierney, J. J. and J. W. Gillespie Jr., "Control of Warpage and Residual Stresses During the Automated Tow Placement Process," *Proceedings of ANTEC 98*, pp. 2356–60, Society of Plastics Engineers, Brookfield, CT, 1998.

Tierney, J. J., D. Heider, and J. W. Gillespie Jr., "Welding of Thermoplastic Composites Using the Automated Tow-Placement Process: Modeling and Control," *Proceedings of ANTEC 97*, pp. 1165–1170, Society of Plastics Engineers, Brookfield, CT, 1997.

Tierney, J. J., R. F. Eduljee, and J. W. Gillespie Jr., "Control of Warpage and Residual Stresses During the Automated Thermoplastic Tow Placement Process," *Proceedings of the 43rd International SAMPE Symposium/Exhibition: Materials and Process Affordability—Keys to the Future*, SAMPE, Covina, CA, 1998.

Wilkins, D. J., "Influence of Fiber Architectures and Manufacturing Methods on Performance Standards," presented at the MIL-Handbook-17 Conference, Portland, OR, June 15–17, 1993.

Wilkins, D. J., M. Ashizawa, J. B. DeVault, D. R. Gill, V. M. Karbhari, and J. S. McDermott, "Comparing Advanced Manufacturing Technology for Polymer Composite Structures in the U.S. and Japan," presented at the 36th International SAMPE Symposium and Exhibition, Anaheim, CA, May 10–13, 1993.

Yang, Y., J. N. Caron, J. B. Mehl, and K. V. Steiner, "Laser Generation and Detection of Lamb Waves in Graphite/Polymer Composite Laminates," *Review of Progress in QNDE*, Vol. 16, eds. D. O. Thompson and D. E. Chimenti, Plenum Press, New York, 1997.

Yang, Y., J. N. Caron, J. B. Mehl, and K. V. Steiner, "Laser Generation and Detection of Surface Acoustic Waves Using Gas-coupled Laser Acoustic Detection," *Review of Progress in Quantitative NDE*, Vol. 18, 1998.

Yang, Y., J. N. Caron, J.B. Mehl, and K. V. Steiner, "Laser Generation and Detection of Lamb-Waves in Graphite/Polymer Composite Laminates," *Review of Progress in Quantitative NDE*, Vol. 16B, Edited by D. O. Thompson and D. E. Chimenti, Plenum Press, New York, NY, 1997.

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E. T. Camponeschi, Jr., J. W. Gillespie Jr., and D. J. Wilkins

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Origin and Influence of Interphase Material Property Gradients in Thermosetting Composites (Ph.D. dissertation)
G. R. Palmese(advisor: R. L. McCullough)

CCM 92-31
Intelligent Manufacturing of Filament-Wound Structures
C. B. Ebersold and S. G. Advani

CCM 92-35
Effective In-Plane Permeability of Multi-Layered RTM Preforms
M. V. Bruschke, T. L. Luce, and S. G. Advani

CCM 92-40
Local Methods for Optimization of Batch Processes
V. Pillai, A. N. Beris, and P. S. Dhurjati

CCM 92-42
Resistance Welding of Dual-Polymer Composites Using a Statistically Designed Experimental Approach
I. Howie, J. W. Gillespie Jr., and A. J. Smiley

CCM 92-43
Resistance Heated Dual Resin Bonding
S. H. McKnight, S. T. Holmes, I. Howie, K. D. Tackitt, J. W. Gillespie Jr., and A. J. Smiley

CCM 92-48
Resin Transfer Molding in Flow Phenomena in Polymeric Composites
S. G. Advani and M. V. Bruschke

CCM 92-50
FEA Techniques for Analyzing Residual Stresses During In-Situ Filament Winding of Complex Geometries Using ABAQUS®
D. D. Coppens, B. Powers, J. W. Gillespie Jr., and R. F. Eduljee

CCM 92-53
A Review of Consolidation Mechanics in Composites Processing
H. H. Lin and S. G. Advani

CCM 92-55
Resistance-Heated Fusion Bonding of Carbon Fiber/PEEK Composites and 7075-T6 Aluminum
S. H. McKnight, S. T. Holmes, J. W. Gillespie Jr., C. L. T. Lambing, and J. M. Marinelli

CCM 92-56
A Predictive Model for Permeability and Non-Isothermal Flow of Viscous and Shear-Thinning Fluids in Anisotropic Fibrous Media (Ph.D. dissertation)
M. V. Bruschke (advisor: S. G. Advani)

List of all participating scientific personnel showing any advanced degrees earned by them while employed on the project

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Roy L. McCullough, Chemical Engineering; Materials Science & Engineering

Co-investigators

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Antony N. Beris, Chemical Engineering

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Azar Parvizi-Majidi, Mechanical Engineering; Materials Science & Engineering

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Michael H. Santare, Mechanical Engineering

Annette D. Shine, Chemical Engineering

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Darin G. Jensen
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Eric J. Lang
Thomas L. Luce
Joseph McCrea
Dennis Michaud
Jeffrey L. Mogavero
Stephanie L. Nesbitt
Michael T. Qaissaunee
Richard W. Rydin
Stephen F. Shuler
Jeremiah Slade
David A. Steenkamer
Kirk D. Tackitt
Erik T. Thostenson

Ph.D. degrees awarded

James N. Caron (Ph.D. Physics '97): *Application of Laser Ultrasonics to Graphite/Polymer Composite Materials*

Jeffrey A. Hrivnak (Ph.D. ChE '97): *Interphase Formation in Reacting Systems*

Eric J. Lang (Ph.D. ME '97): *Intelligent Textile Composite Materials Containing Lineal Strain Sensors*

David L. Fecko (Ph.D. MSE '96): *In-Situ Ultrasonic Porosity Monitoring for the Thermoplastic Matrix Pultrusion Process*

Richard W. Rydin (Ph.D. MSE '96): *Using the Drop Weight Impact Tower to Evaluate the Impact Resistance of FRP Composite Plates*

Stephen F. Shuler (Ph.D. ME '96): *Rheology and Forming of Long-Fiber- Reinforced Thermoplastic Composite Materials*

Vikram K. Pillai (Ph.D. ChE '94): *Use of Simulations in Optimization of, and Development of a Knowledge-Based System for, a Composites Manufacturing Process*

David A. Steenkamer (Ph.D. ME '93): *The Influence of Preform Design and Manufacturing Issues on the Processing and Performance of Resin Transfer Molded Parts*

Master's degrees awarded

Kenric M. England (M. MSE '97): *Direct Current Sensing of Viscosity and Degree of Cure of Vinyl-Ester Resins*

Jeffrey Mogavero (M. ME '97): *Compression Characterization and Resin Infiltration of Multi-Layered Preforms in Resin Transfer Molding*

Thomas L. Luce (M. ME '96): *An Experimental Investigation of the In-Situ In-Plane and Transverse Permeabilities of Fiber Preforms*

Dennis J. Michaud (M. ChE '96): *Investigation of Curing Behavior in Thick Thermoset Composites Manufactured by Resin Transfer Molding*

Scott T. Holmes (M. ME '95): *Influence of Surface Modification on the Processing and Performance of Aluminum Adhesive Joints Bonded with Thermoplastic Polymers*

James N. Caron (M.S. Physics '95): *Methods for Studying Ablation Phenomena Using Laser Ultrasonics*

Stephanie L. Nesbitt (M. ChE '95): *Cure Chracterization of Bismaleimides*

Jeffrey A. Hrivnak (M. ChE '94): *Optimization of the Surface Free Energy on Carbon Fibers and its Effect on Interphase Formation*

Michael T. Qaissaunee (M. ME '93): *Interaction Between and Edge Dislocation and a Single-Phase and Two-Phase Elliptical Inclusion*

Report of inventions

Gas-Coupled Laser Acoustic Detection, J. N. Caron, J. B. Mehl, and K. V. Steiner, U.S. Patent Application Serial No. 08/840,968, 1998.